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DEVELOPMENT OF A FIXED BASE VISUAL APPROACH AND LANDING SIMULATOR

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THESIS

DEVELOPMENT OF A FIXED BASE VISUAL
APPROACH AND LANDING SIMULATOR

by

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Development of a Fixed Base Visual
Approach and Landing Simulator

by

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ABSTRACT

A fixed base visual approach and landing simulator was developed using an F-105 Canopy/Seat Cockpit Trainer, Panasonic Closed Circuit Television System, and a SMK-22 Main Attachment Unit. Difficulties encountered in interface of the units necessitated modification of the SMK-22 Attachment Unit in both flight characteristics and operating modes. A main control console was assembled to control and coordinate the operation of the system elements and monitor the system during simulated flight. Reduction in degrees of freedom was achieved through elimination of the yaw mode. An FJ-4 control stick was modified and installed in the cockpit replacing the fabricated control stick. Longitudinal trim control was achieved with the trim switch installed in the FJ-4 control stick, modifying longitudinal circuitry by means of an additional trim assembly.

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I. INTRODUCTION

Simulation of aircraft flight is accomplished by employing techniques varying from the use of digital computers which analyze proposed aircraft to employment of complete operational flight trainers. In mathematical simulation, equations of motion combined with individual aircraft characteristics and environmental conditions are calculated yielding solutions in the form of printed output.

Pilot training and evaluation, on the other hand, is conducted through the use of highly complex operational flight trainers which duplicate the dynamics of a particular aircraft along with varying environmental conditions. Scientific research must draw on both fields in order to investigate specific areas of interest. Simulators in this field must have the capability to simulate various aircraft types and flight regimes along with a sufficiently sophisticated computer system in order to obtain realistic results.

The procurement of a U.S. Air Force SMK-22 Visual Simulator Main Attachment Unit afforded an excellent opportunity to investigate several areas of current interest in aeronautical research. These areas include comparison of displacement and force control sticks in both center and side-arm mounted modes. An additional benefit obtained from development of the visual flight simulator is its use to complement the Mini-link Analog Flight Simulator previously developed at the Naval Postgraduate School.

The purpose of this thesis was to develop and modify, if necessary, the simulator in order to provide realistic simulation of the behavior of a single engine jet aircraft in the approach and landing phase of simulated flight. An additional requirement was to increase the versatility of the system to accept various types of flight controls.

II. DISCUSSION

A. BACKGROUND

The SMK-22 system was designed to operate with several types of operational flight trainers including the P3A, C11C and B52. Through the use of the SMK-22 landing simulator, visual landing and take-off capability can be combined with simulated operational flight providing complete flight simulation. The SMK-22 main attachment unit consists of a belt mechanism, lighting system, television support mechanism and control panel. It employs servomechanisms for belt drive, television camera attitude and positioning.

An operational flight trainer was not available to provide input signals to the landing simulator, therefore a means of signal generation had to be fabricated that was compatible with the input characteristics of the main attachment unit. This was accomplished by means of potentiometer tap-offs from throttle and flight controls mounted in an F-105 cockpit/seat trainer. Significant problem areas encountered pertained to matching signal output with attachment unit input restrictions in both magnitude and range. In addition it was desired to achieve control of all the components of the system, vary certain parameters and monitor the visual display as seen by pilots from one location. To accomplish this, a control console was assembled, consisting of a television repeater, attachment unit controls, and variable d.c. power

supply.

In visual simulation equations of motion, aircraft characteristics and simulated environmental conditions are processed by a computer, which provides output signals. These signals can be utilized to drive cockpit instruments, generate a contact display (projected geometric patterns representing section lines on the earth's surface), or drive a camera assembly. The visual presentation furnishes feedback to the pilot indicating relative aircraft position from which further corrections can be made.

There is no computer section in the SMK-22 main attachment unit. The fixed base approach and landing simulator system is limited to receiving signals derived from control deflections and throttle settings. These signals are scaled and combined to drive the runway belt and camera assembly, which in turn gives the pilot a pictoral presentation of the approach and landing (Figure 1).

Variations for individual aircraft characteristics and flight conditions must be applied electrically at appropriate points in the SMK-22 Control Panel Assembly.

In a limited sense, the SMK-22 functions as an Analog device. Input signals received are scaled, balanced and amplified in order to drive the various servomechanisms. Potentiometer feedback tap-offs on the camera assembly are combined with inputs to provide signals for lateral rate and altitude.

B. COCKPIT

Difficulties encountered in cockpit utilization were primarily associated with the original control stick (Figure 4). The magnitude and range of signal outputs were unacceptable. Lateral movement of the control stick was insufficient (approximately plus or minus 20°). The springs utilized in both fore and aft and lateral movement were compression type. The high breakout forces encountered (2-3 lbs.) coupled with short angular displacement caused considerable over-shoot. Reliability of the control stick was poor in that Allen screws which secured tap-off potentiometers to stick pivot axes kept loosening, necessitating realignment of the system. The friction of the plastic bushings was so high that it disguised the stick center position. There was no provision for including longitudinal trim control on the stick.

The number of shortcomings in the original stick indicated a definite need for replacement. An FJ-4 Fury control stick assembly was available, but the base dimensions and gear drive ratios were inappropriate for direct installation. In order to facilitate its use, the forward part of the cockpit console was widened, and the stick assembly (Figure 5) was installed.

An important factor in signal generation is the manner in which the SMK-22 main attachment unit processes signals. Rates of movement (linear and angular velocity) are essentially fixed. Variation of these rates over a small range is possible through use of trim potentiometers. Angles of bank and pitch are functions of stick deflections.

Roll and descent rates are fixed in a similar manner. This situation meant constant stick deflection was required to hold an angle of bank or nose down attitude. The solution to this problem will be discussed later.

The nature of this characteristic was such that a wide range of potentiometer travel was required for full bank and pitch. This was accomplished by changing gear ratios and substituting potentiometers of lower resistance for both pitch and roll. This eliminated the "jittering" effect of the potentiometer wiper arm traveling through small angular displacements over a few turns of resistor wire. The physical aspects of the FJ-4 stick include:

$\pm 35^{o}$ roll

$\pm 25^{o}$ pitch

4^{o} nose-up to 8^{o} nose down trim variation

1.1 pounds-per-inch pitch

1.0 pounds-per-inch roll

Friction is negligible. Tension can be easily increased by mounting additional springs at base of assembly.

The need for constant stick displacement for constant pitch angle was eliminated by including the capability of longitudinal trim control. It was necessary to fabricate a switching device which adjusted this constant deflection signal to various pitch angles. The assembly uses a motor driven potentiometer to furnish a constant pitch signal. The trim switch in the FJ-4 stick was connected to the assembly which was

mounted in the left-hand console bay. The trim position is varied by energizing the potentiometer drive through the stick trim switch, changing the value of the basic pitch signal (Figure 2).

The remaining constant signal-deflection requirement, that of roll, was eliminated by disconnecting the feedback signal from the roll potentiometer tap-off mounted on the camera assembly.

Instrumentation in the cockpit consists of an altimeter, airspeed indicator, remote closed circuit television repeater, and flight-path deviation-indicator ID-249 (Figure 6).

C. SMK-22

The main attachment unit (Figure 7) presented several difficulties. The major area requiring modification was the vertical mode of the camera assembly. The altitude that the camera assembly assumes is a function of voltage. Approach began at a relatively low altitude of 600 feet above the runway. In addition the rate of descent or climb is virtually fixed (variable over small margin by trim potentiometer on control assembly). The rate of closure to runway is altered by varying the throttle setting, thereby adjusting the airspeed and relative rate of closure. An additional limitation to operation of the main attachment unit was the inability of the camera assembly to pass through the nose level position, in other words, stop a rate of descent and commence climbing. This limitation was due to the use of alternating current for signal output and servomechanism drives. There was no capability to reset the camera assembly at rates of climb other than 500-700 feet-

per-minute. This required long delays between runs.

The limitations of slow altitude reset and inability to climb and descend in the same run were eliminated through the use of a fabricated vertical rate assembly (Figure 3). The assembly uses relays which adjust range of motion of the camera assembly as it passes through the nose level position (Figure 8).

Fast reset was accomplished through the use of a motor driven potentiometer which increases the altitude voltage at a high rate. An additional feature was included in the vertical rate assembly which automatically resets the camera assembly as soon as a landing is made.

The descent rate trim potentiometer was replaced with a ten turn potentiometer and moved to the control unit. A manual altitude reset control was added to the main attachment unit and also mounted on the control unit.

Operation of the camera assembly was hampered by high azimuth rate. Roll input signal yielded excessive rates of turn of the camera assembly. In addition, interference from the ultraviolet lamps used to illuminate phosphor coated runway lights caused 15° yaw excursions to right whenever these lights were energized. Inclusion of a 1000 ohm variable potentiometer in series with azimuth rate servomotor to attain acceptable rates of turn was unsuccessful. The resulting reduced voltage caused a hesitating motion in azimuth rate. At this time the decision was made to freeze yawing motion of the camera assembly.

Changes in the visual presentation were considered to be negligible, inasmuch as a pilot does not fix his eyes to the aircraft's longitudinal axis but rather focuses his attention on the landing area during an approach. The major visual input therefore is lateral motion with respect to the runway center line. In this respect, the frozen azimuth of the camera assembly duplicates the function of the pilot's eyes. In flying the simulator in this configuration, it was found that lateral motion combined with rate of closure and yielded apparent motion in a direction several degrees to the right or left of center line.

The television camera proved to be highly sensitive to available light. The visual presentation with the main attachment unit doors secured and ultraviolet light energized was so detailed that the runway belt and belt track were visible (Figure 9). A polarized filter was mounted on the camera lens thereby masking all but the landing lights and strobe.

D. CONTROL CONSOLE

To facilitate control and monitor operation of the system, the original control console was reconstructed and mounted in a vertical equipment cabinet (Figure 10). The components of the console consist of a Sony television, variable d.c. power supply, SMK-22 Main Attachment Unit function controls, and main circuit breaker.

Included in the attachment unit section of the console are the emergency power cut-off switch, visibility limitation filter adjustment control, and rate of climb/descent control.

The variable d.c. power supply was used to power the longitudinal trim and vertical rate assemblies.

III. CONCLUSIONS

A. CAPABILITIES

The goal of this thesis project was accomplished. The fixed-base visual approach and landing simulator closely duplicates the motion of a jet aircraft in the landing configuration. Elimination of the azimuth mode does not significantly degrade the performance of the system. The physical characteristics of the FJ-4 stick are reasonably realistic. Approaches flown in the simulator can be aborted and climbs commenced.

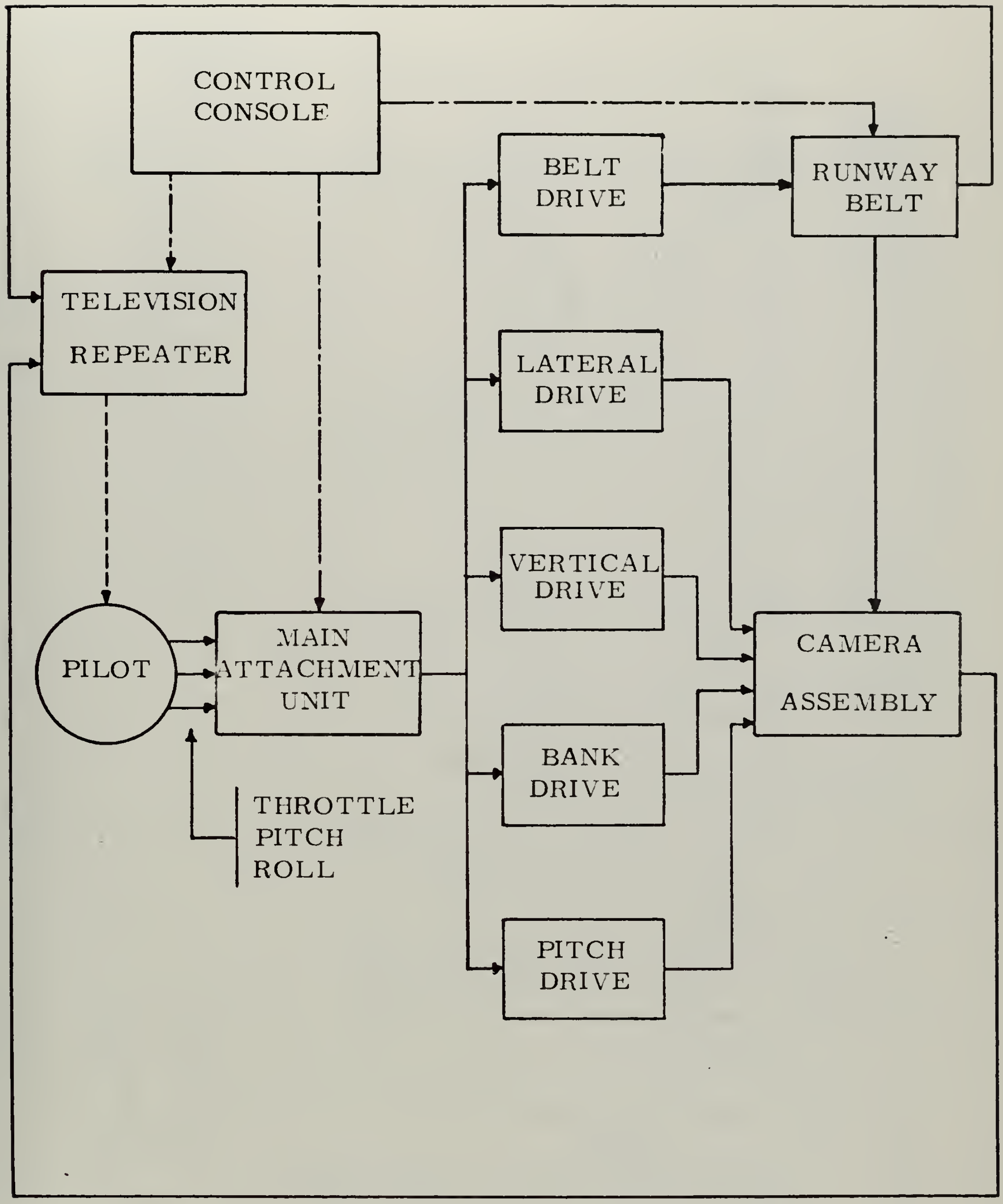
B. LIMITATIONS

Rate of descent remains fixed for the pilot. Operation of the flight-path deviation-indicator horizontal needle begins at 500 feet indicated altitude, although approach commences at 600 feet. Stick force is somewhat low and its motion is undamped.

IV. RECOMMENDATIONS

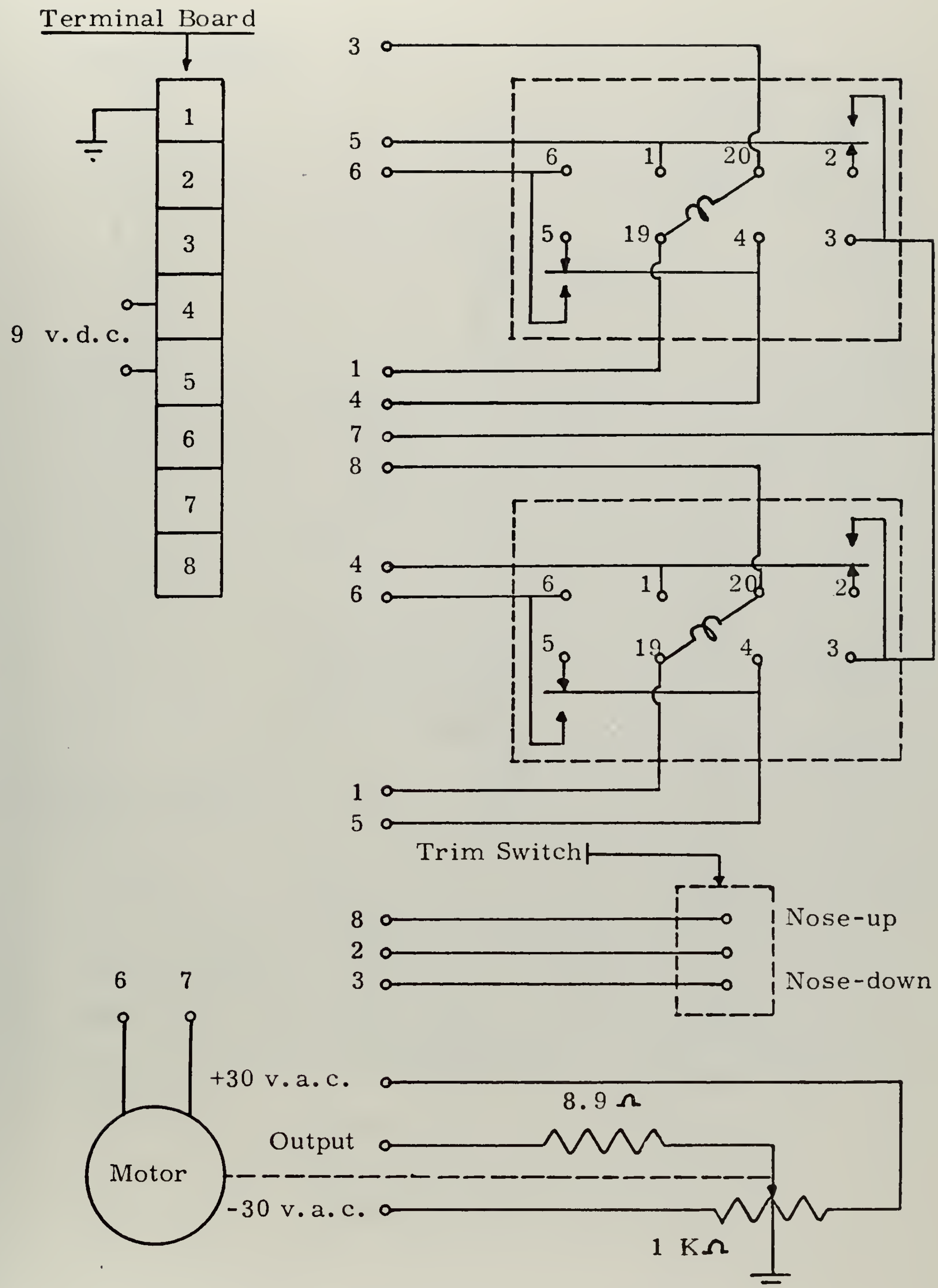
It is recommended that evaluation of flight controls be initiated using the FJ-4 stick. Preliminary designs of a side-mounted displacement stick have been considered prior to termination of this thesis project. It is anticipated that significant areas in fabrication of the side stick will involve choice of springs, type of linkage, gear ratios and signal scaling.

A highly feasible future use of the simulator system would be its conversion to an aircraft carrier landing simulator by marking a flight deck on the rubber belt. A minor landing aid can be produced with fiber optics.



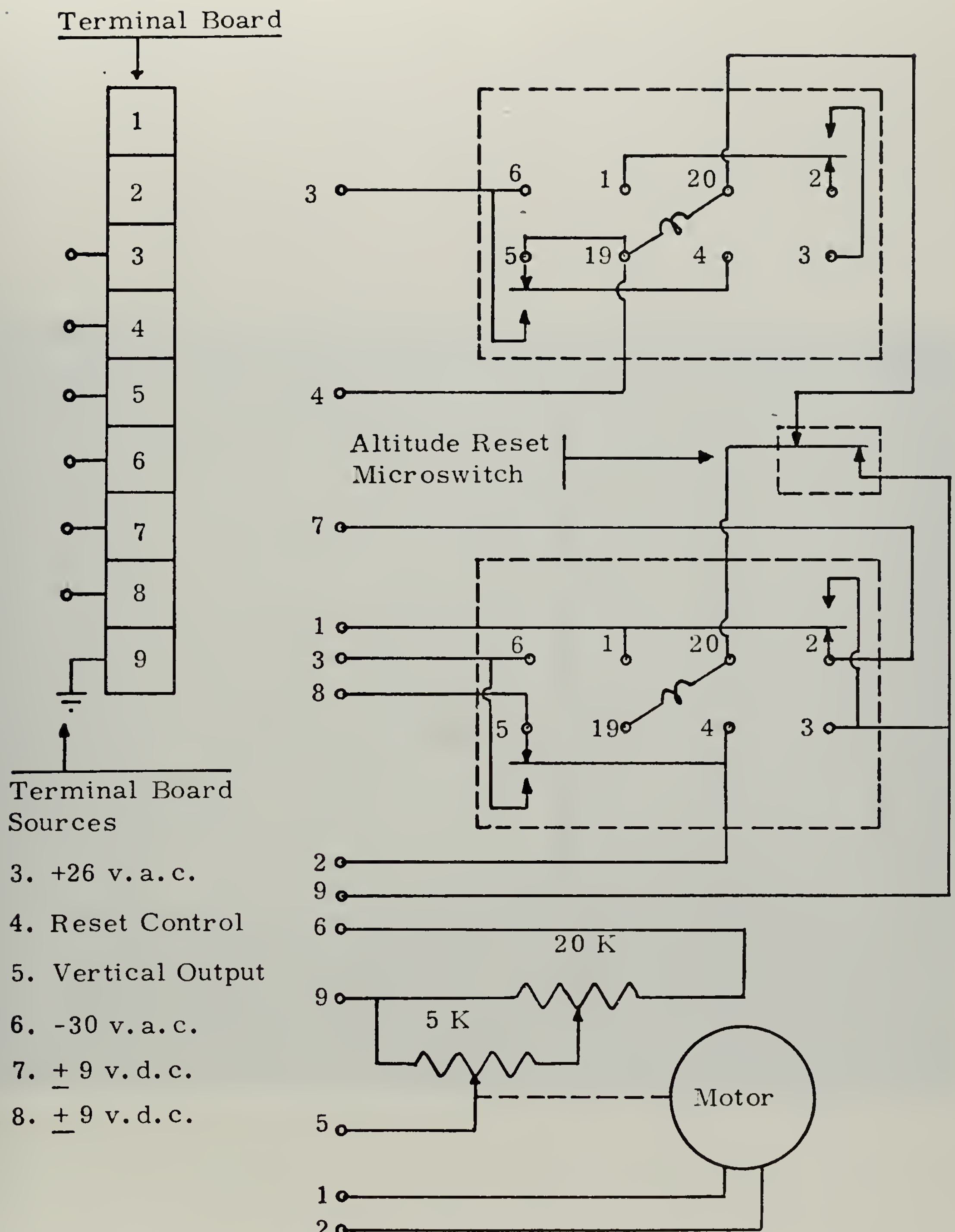
Simplified Block Diagram

Figure 1



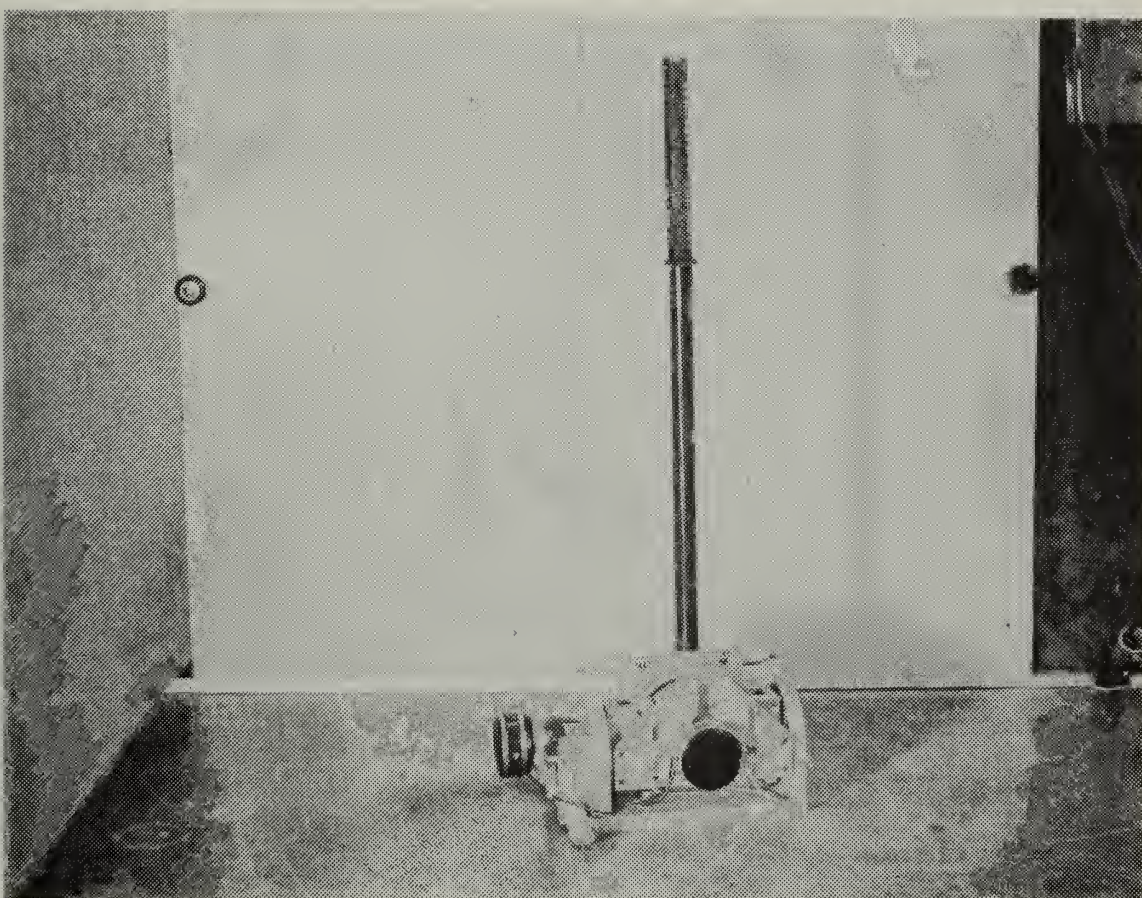
Longitudinal Trim Assembly

Figure 2



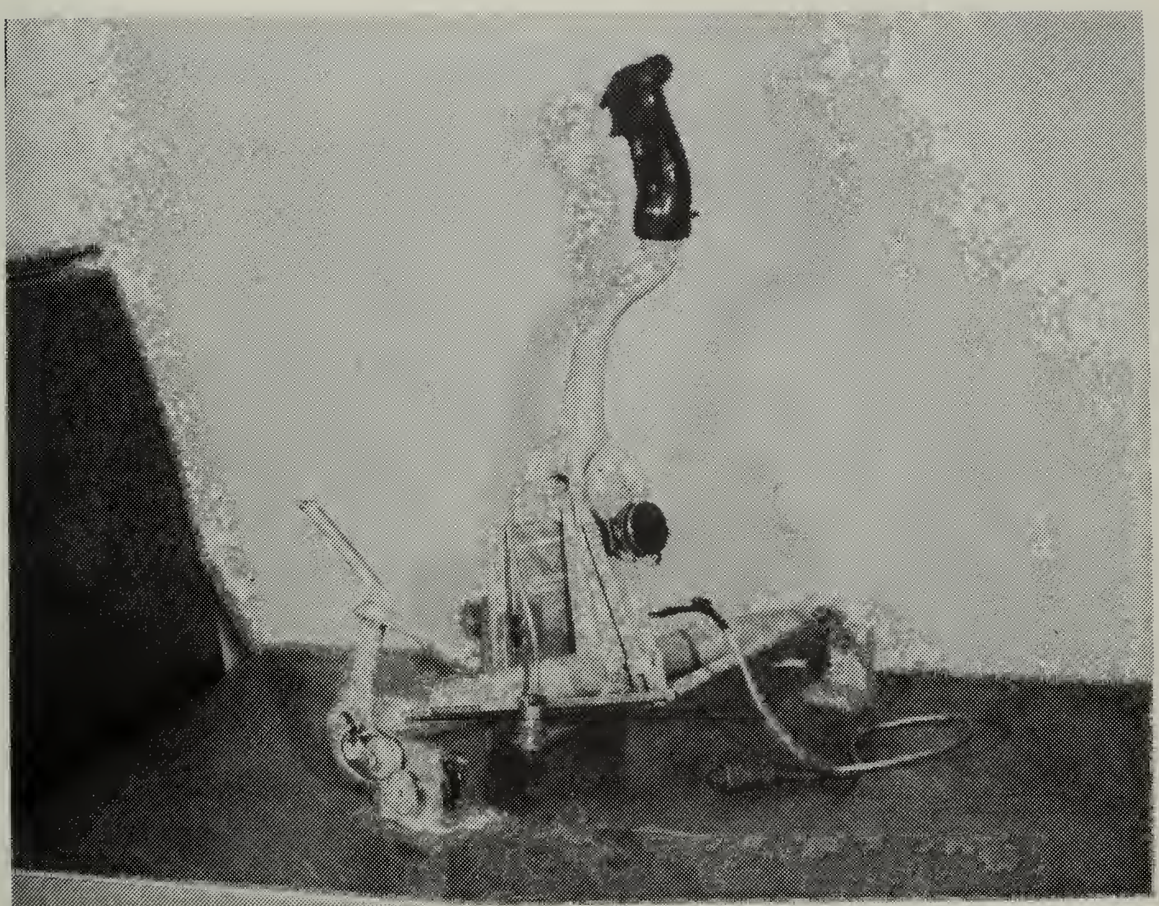
Vertical Rate Assembly

Figure 3



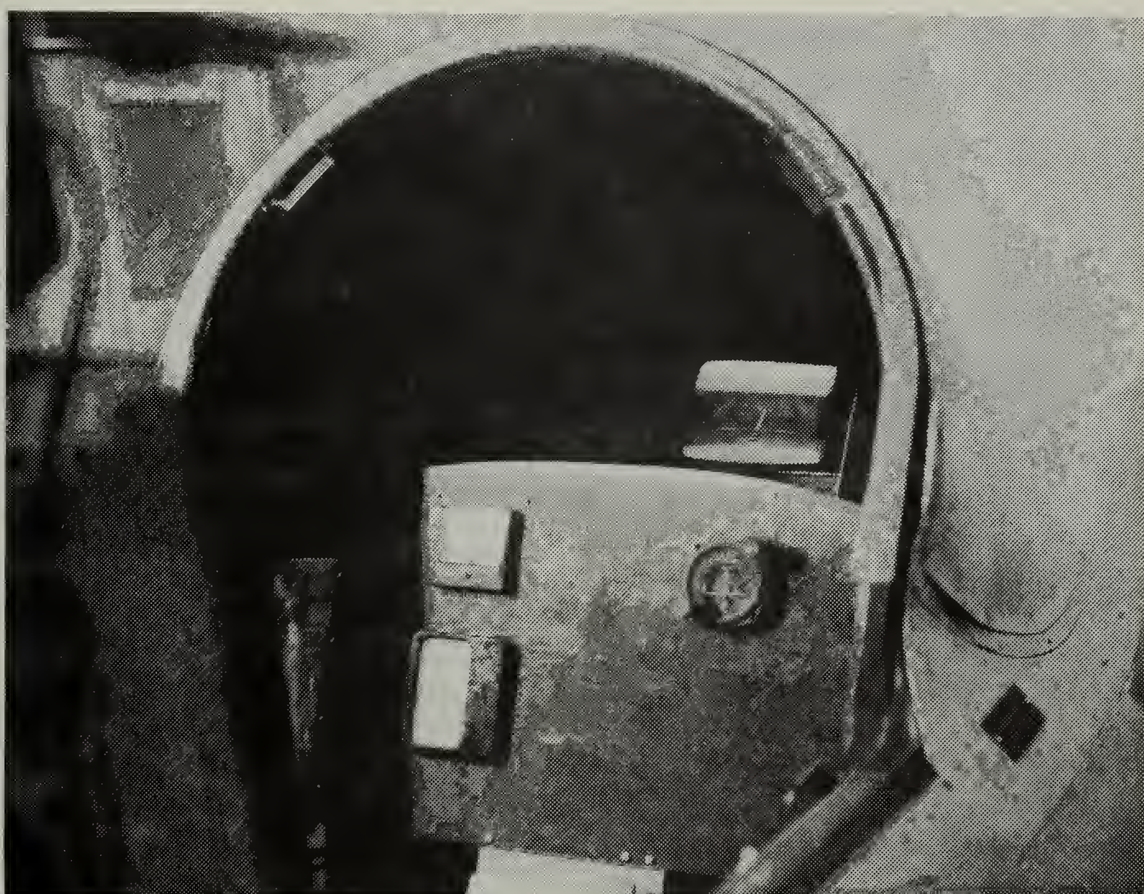
Stick

Figure 4



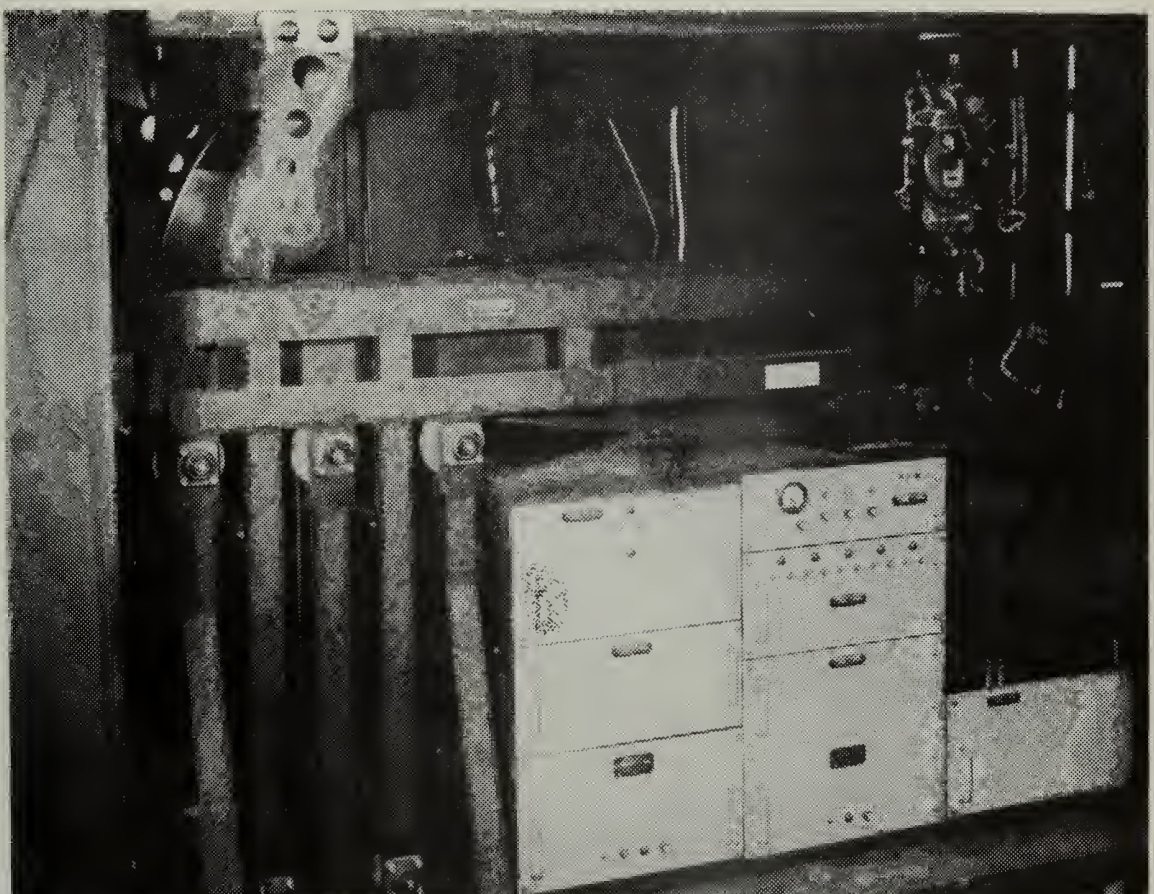
FJ-4 Stick

Figure 5



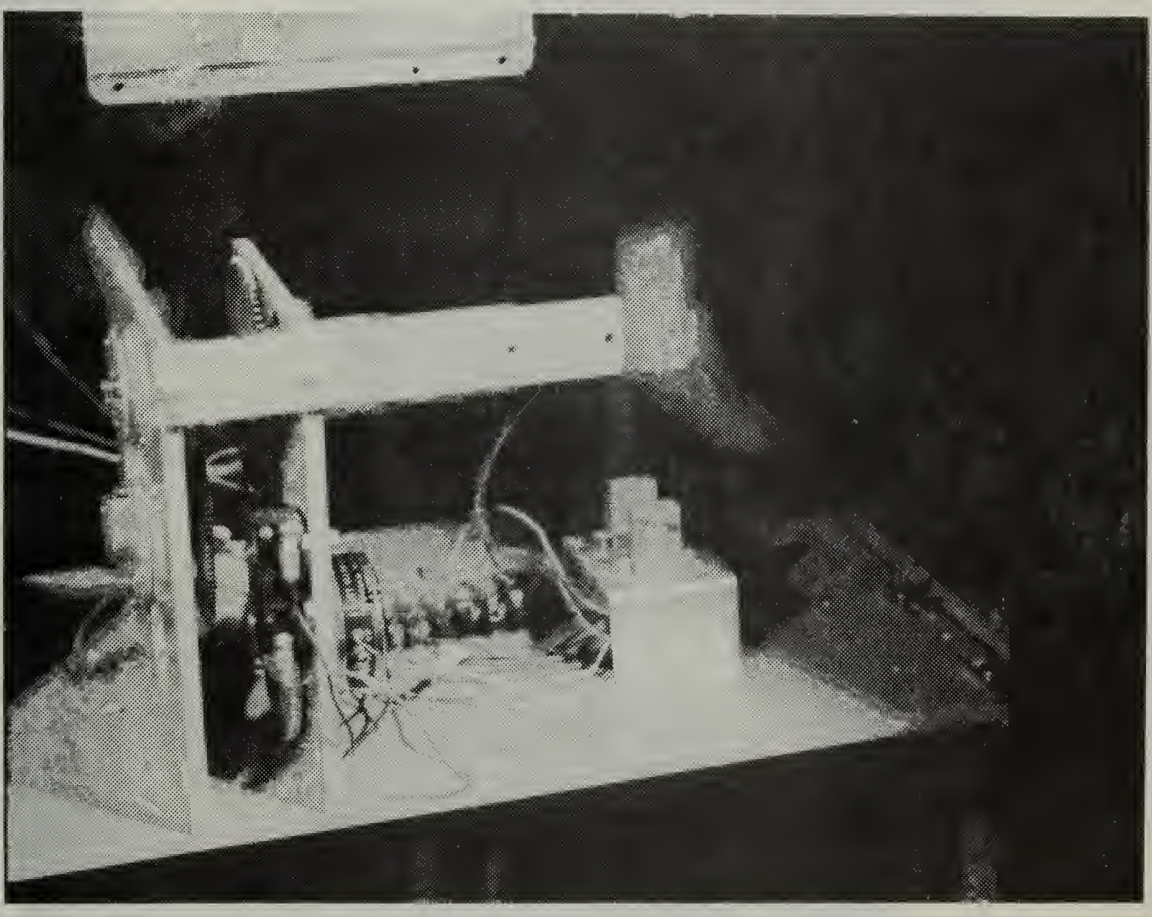
Instrument Panel

Figure 6



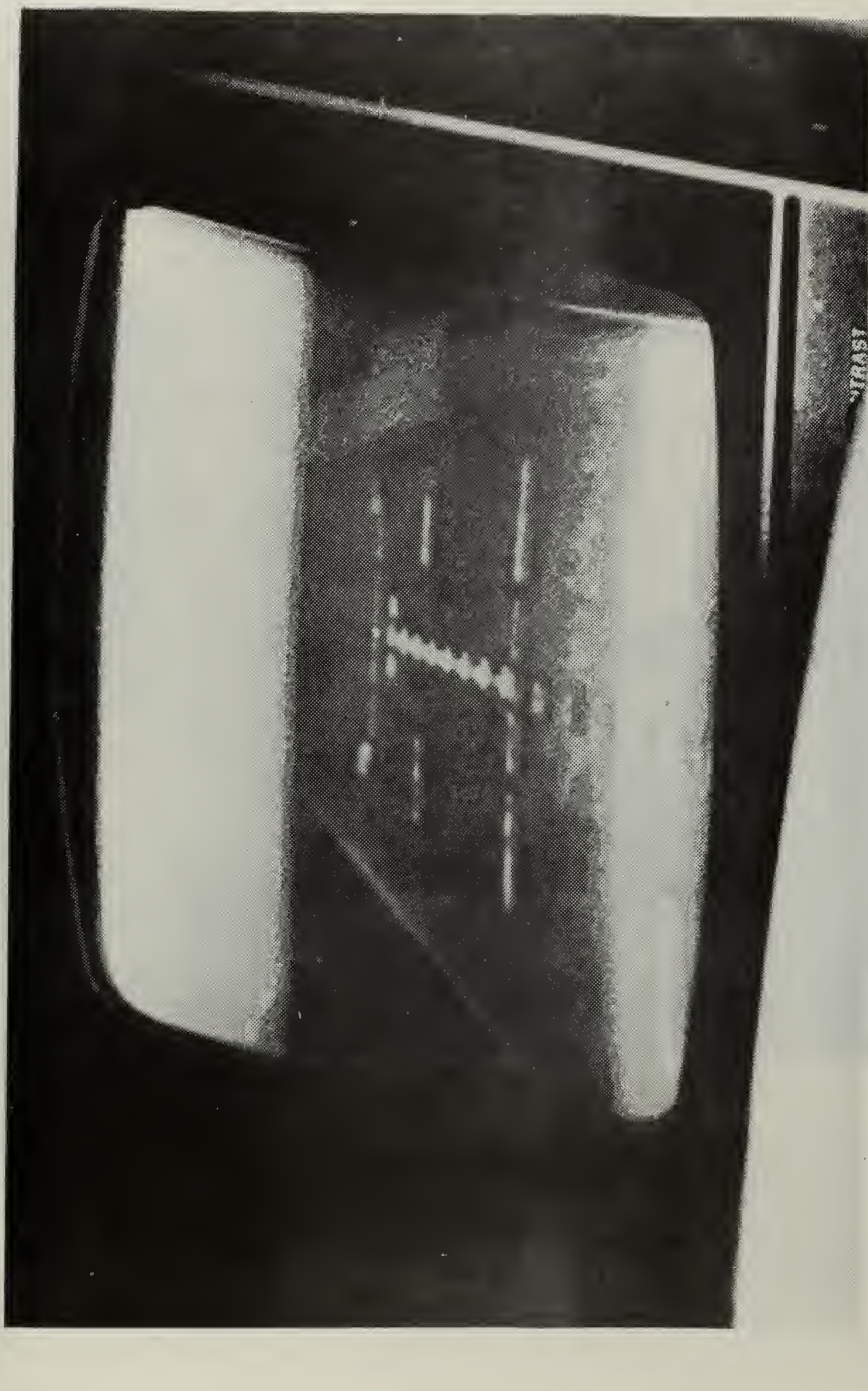
SMK-22

Figure 7



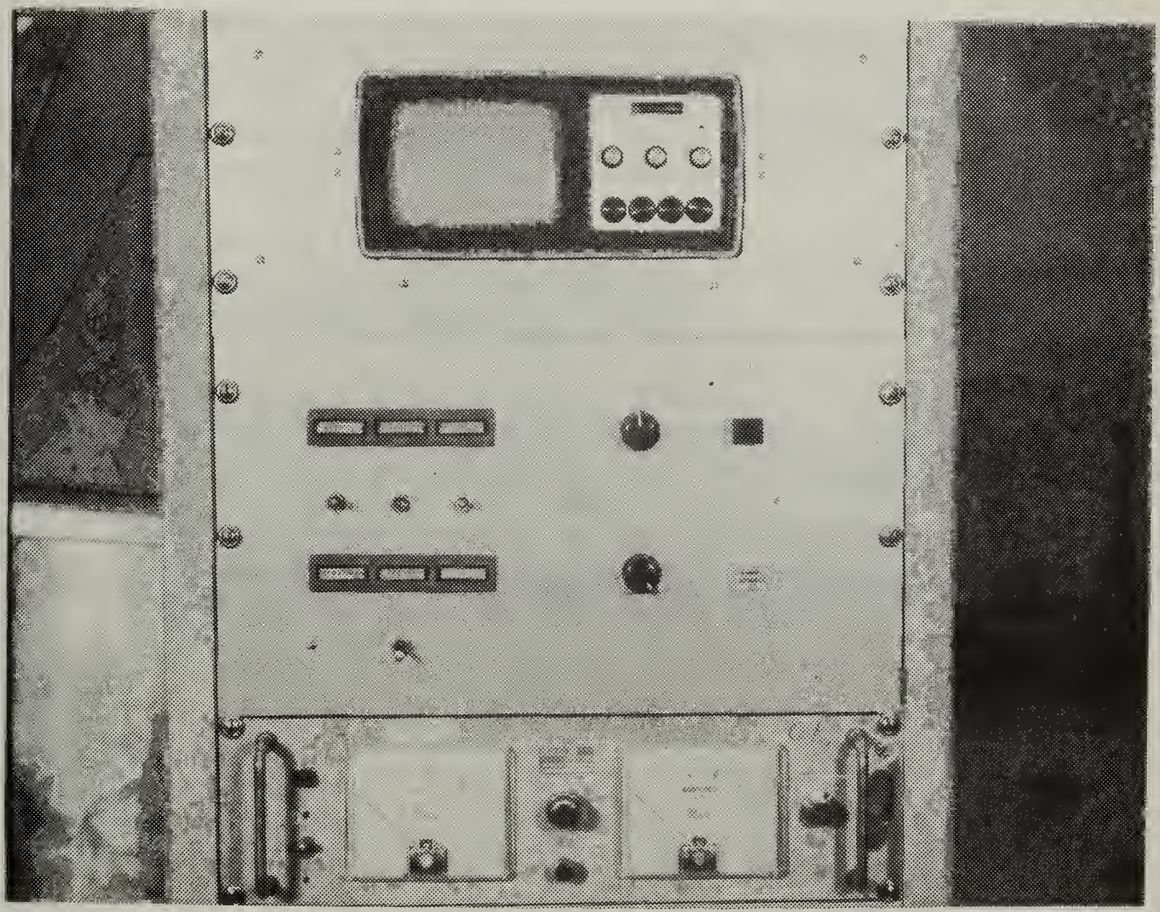
Vertical Rate Assembly

Figure 8



Cockpit Presentation

Figure 9



Control Console

Figure 10

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13. ABSTRACT

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KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Flight simulator						
Landing simulator						
Approach simulator						
Visual simulator						

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